Electricity Price and Southern California's Water Supply Options

Larry Dale, Lawrence Berkeley National Laboratory
Camilla Dunham Whitehead, Lawrence Berkeley National Laboratory
Andre Fargeix, Golden Gate Economics

Electricity Price and Southern California's Water Supply Options

Abstract

This paper evaluates the impact of fluctuating electricity prices on the cost of five options to increase the water supply to urban areas in Southern California - new surface storage, water purchases, desalination, wastewater recycling, and conservation.

We show that the price of electricity required to produce and transport water influences the cost of water supply options and may alter the decision makers economic ranking of these options. When electricity prices are low, water purchase is the cost-effective option. When prices exceed \$86/MWh, conservation of electricity and water through installation of high-efficiency clothes washers is the most effective option.

Introduction

Since the 1990 Census, the population of Southern California has grown by 13 percent to 16.5 million (US Census, 2000). Los Angeles County grew by almost 700,000 from 1990 to 2000 - the largest increase in the state (US Census, 2000). Indeed Los Angeles County, with 9.8 million people, has a greater population than 42 states in this country (LA County Government, 2002). To accommodate this increased population and meet current and future water needs, new water resources must be developed for the region.

This paper evaluates the impact of fluctuating electricity prices on the cost of five urban water supply options to Southern California: new surface storage, water purchase, desalination, recycling, and conservation. There are large differences in the amounts of energy used to supply water following each of these options. Surface storage generates electricity when stored water is released and flows through hydropower generation facilities but uses energy for delivery to point of use. Water purchases require energy to deliver water from farms to cities. Water treatment (desalination and water recycling) uses energy to clean and desalt water. As an example of conservation, we select the replacement of washing machines because the benefits of this option are particularly sensitive to changes in California electricity prices. In this case, water conservation efforts save energy as well as water. Thus, the unit supply cost of each option varies markedly, depending upon the price of electricity.

The paper applies a spreadsheet model to evaluate changes in the unit supply cost of water under the five options for a broad range of electricity prices. The paper is focused on changes in water operating costs caused by changes in electricity prices. Electricity costs may impact the cost of capital, such as reservoir construction, needed to supply water but this impact is expected to be relatively minor. For example, electricity and other utility charges combined make up only .3% of the total direct cost of constructing dams and conveyance facilities (California Department of Water Resource, 1980). The paper concludes that, if electricity prices are low, water purchase is the cheapest option and conservation is the most expensive. If electricity prices are high, conservation is the cheapest option and desalination is the most expensive. At the 2001 price of electricity (\$86 per MWh), the lowest-cost options are water purchase and conservation.

The remaining portion of the paper is divided into four sections: in the first two sections, basic costs of all five options are defined and compared; in the third section, the electricity used (and, where relevant, generated) by each option is examined; and, in the final section, the sensitivity of the analysis to electricity prices is discussed.

Baseline Costs

Table 1 summarizes the costs of the five supply options considered in this paper. Costs include production, transportation from the source to the local urban water agency's distribution network, and treatment. Costs do not include distribution costs (within the local water network), environmental costs (e.g., solid waste disposal) or security (e.g., protecting dams from sabotage) costs.[1] These costs are assumed to be equal across options. Table 1 does not take into account the energy benefits of options (such as electricity generated by water that would be released from the enlarged Shasta reservoir or the energy savings from water conservation). These benefits will be analyzed in subsequent sections. We refer to "base costs" as the costs of water supply at a standard electricity price of \$50/MWh. Base costs include both capital costs and O&M costs. Our paper compares the per acre cost of different water supply options under various assumptions regarding electricity prices.

<u>New Surface Storage</u>. The authors chose enlargement of the Shasta reservoir as the surface storage option because this would be the most favorable choice for energy production relative to the other surface storage options selected by CALFED in the EEWMA. The other surface storage options were more expensive than the Shasta option and would not generate electricity. It should also be mentioned that Shasta is expected to provide environmental benefits, including in stream flow and temperature benefits that have not been included in this study.

The costs of new surface storage and purchase options are taken from this study (Dale, 2001). That document estimates the unit cost (and yield) of water from an enlarged Shasta reservoir without accounting for electricity benefits. Enlarging Shasta would require an investment of \$174.8 million (including engineering, regulatory, construction, and contingency costs). Annual operations and maintenance (O&M) would amount to \$2.0 million, for a total annualized cost of \$13.1 million over a 50-year period.

CALFED's EEWMA estimates the yield of the Shasta project at 129,000 acre-feet (159M m^3) per year. However, additional analysis (Dale, 2001) shows that in practice the yield will be greatly reduced by competition for the same water supply from other supply sources, including low-cost conjunctive use and water-purchase options. If the water supplied is dedicated to urban areas and competition from other supply sources is taken into account, Shasta's yield drops to 25,600 acre-feet (31.6M m^3) per year. Therefore, the cost for urban use is estimated at \$512 per acre-foot (\$0.4/m^3), which is much higher than CALFED's EEWMA estimate. Shasta project is expected to generate environmental benefits not accounted for in this study.

<u>Water Purchases</u>. Another source of water is purchase from agricultural users. Because of their location, the most likely sellers would be farmers in the San Joaquin, Tulare, and Colorado River Basins. Based on water market data collected during the past 10 years, Dale (2001) estimates

[1] The cost structure is similar to the one used in CALFED's "Economic Evaluation of Water Management Alternatives" (EEWMA), (CALFED, 1999) except that the EEWMA measures costs before treatment and adds a negative cost adjustment to supply sources (such as conservation or desalination) for which treatment is already included in production costs.

that San Joaquin and Tulare basin farmers would be willing to sell water at prices ranging from \$55 per acre-foot (\$0.04/m^3) in wet years to \$200 per acre-foot (\$0.16/m^3) in dry years. These prices are supported by the CALFED demand studies described in the EEWMA. For the Colorado River basin, a cost of \$230 per acre-foot (\$0.19/m^3) for our analysis was used; this cost corresponds to EEWMA's dry-year estimates for the first 290,000 acre-feet (357.7 Mm^3) of new supply. (The dry-year cost is used because that is when new water supply would be in demand.)

Desalination. Several versions of seawater desalination plants are under consideration in Southern California. One recent example is being investigated by the Municipal Water District of Orange County (MWDOC). That proposed plant would cost \$200 million and would have a capacity of 50 million gallons of water per day (189.3 km^3). Estimates indicate that water from this plant would cost \$788 per acre-foot (\$0.64/m^3) (*Orange County Register*, 2001). In the MWDOC case, the plant would require construction of a pipeline and pumping facilities to bring water to the public network. Pipeline costs would add approximately \$200 per acre-foot (\$0.16/m^3) and include the total cost to build facilities and pump water to the public network (Lee, 2001). The transport cost in this case would add about \$100 per acre-foot (\$0.08/m^3), depending on location.

Wastewater Recycling. The costs of recycling projects vary because of differences in influent water quality and projected use of the treated water among other characteristics. For instance, the water produced by the first phase of the proposed Orange County Groundwater Replenishment System would not increase drinking water supply but would be used for replenishing the groundwater aquifer and creating a seawater intrusion barrier (Jajliardo, 2001). The project's yield is predicted to be approximately 70,000 acre-feet (86.3 Mm^3) at an annualized cost of \$420 per acre-foot (\$0.34/m^3).

In the past, very few recycling projects were built to supply drinking water. One recently proposed project for this purpose is the San Diego Water Repurification System, which would produce 15,000 acre-feet per year (18.5 Mm^3) at a cost of \$580 per acre-foot (\$0.47/m^3). Water would be routed to a conventional treatment plant before distribution. The project is currently on hold.

Conservation. The conservation option entails providing a large portion of Southern California households with new washing machines.[2] The newest washing machines can reduce energy use by 67 percent and water use by 46 percent (US DOE, 2000). If five million Southern California households or 30% of the total households, installed the newest washers, this option would generate 109,000 acre-feet of water per year (134.4 Mm^3). The cost of conservation is based on a Department of Energy (DOE) analysis of water use by energy-efficient washing machines. The cost of new, efficient (generally front-loading) washers is currently around \$700; less-efficient (top loading) washers cost \$500. The authors evaluated alternative replacement programs that

---

[2]We selected washing machines as one of the more cost effective options for conserving both water and electricity over the next 10 to 20 years. In the long run, other conservation options should be considered. Preliminary analysis of these options indicates that irrigation/landscaping and leak detection would save the most water; appliance and lighting replacement would save the most energy; but clothes washing machine replacement offers the highest combined electricity and water savings.

would proceed at three different rates - fast , gradual, and intermediate. Under a fast-paced program, new washing machines would be purchased to replace all currently installed machines. Under a gradual approach, households would receive incentives to switch to front-loading machines only when their old machines became obsolete (washing machines typically last 15 years). The intermediate approach assumes replacement of all machines over seven years.

Experience in Washington State shows that with the WashWise rebate incentive program, Seattle has avoided cost of new sources of water supply valued at approximately $1.4 million from the rebated machines alone. For the 25,171 efficient machines Seattle has rebated (1997-2001), the savings are 352,000 gallons (1.3 km^3) per day of water (@13.98gallons/day/machine) (@0.05 m^3), and 31,000 kWh/day (@ 1.23 kWh/day) of electricity -- assuming electric hot water and dryers. In addition, the washers save energy and reduce sewer flows (Dietemann, 2002).

Base Cost Comparison

Table 1 summarizes the estimated yields and unit costs of the supply options considered in this analysis. To make costs comparable among all alternatives, transportation and treatment costs were added to basic production costs when relevant.

Without taking into account the electricity benefits of each option, unit costs range from $400 per acre-foot ($400/m^3) (for water transfers) to more than $3,000 per acre-foot ($2.4/m^3) (for a fast-paced washing machine replacement program). However, these estimates change dramatically once electricity benefits are taken into account.

Electricity Generation and Use

New Surface Storage

<u>Generation</u>. Enlarging the Shasta reservoir increases the amount of electricity that can be generated at the reservoir dam. However, electricity would be required to deliver water from the reservoir to Southern California. The enlarged Shasta would decrease reservoir spill by an average of 75,400 acre-feet per year (93 Mm^3) (USGS, 2002) and increase reservoir elevation (lake level) by approximately eight feet on average. (Of that amount, 54,600 total acre-feet (67.3 Mm^3) would be put to beneficial use. However, new water supply to Southern California urban users is only 25,600 acre-feet (31.6 Mm^3) largely because of reductions in supply from other water sources north of the Delta, including conjunctive use programs. In this scenario, it is assumed that all new water is purchased by Metropolitan Water District (MWD).)

Decreased spill and higher lake elevation increase electricity generation from the reservoir. Each year, there is limited water flow over and above the amount needed to meet in-stream flow standards and relatively senior existing water rights; this limited additional flow is available for either surface or subsurface storage. Any new water supply option would capture some of this flow decreasing the amount available for capture and storage by other water supply options. Decreased spill adds to the amount of water directed through the electric turbines at the Shasta power plant rather than spilled away from the turbines. This is about 1.5 percent of the current average annual release from Shasta.. The higher lake elevation increases reservoir "head" and thus the amount of electricity generated from each acre-foot of water released from Shasta.

Reservoir head is the principal variable affecting the amount of electricity generated at the turbines per acre-foot of water released. Figure 1 is a plot of the relationship between reservoir elevation and unit electricity production (kWh/ft3) since 1997. The graph is based on USGS data for historical water levels, water releases for electricity, and electricity production at Shasta dam. Note that the relationship between the two variables in Figure 1 is almost perfectly linear.[3]

This linear relationship is used to estimate energy production for the Shasta enlargement option in the Water Management Alternatives Post-Processing Spreadsheet Model. With that model, electricity generation is shown to increase an average of 65,754 MWh per year under the Shasta enlargement option (See Table 2). Hence, new electricity generation is 2.67 MWh for every acre-foot of new yield.[4]

Delivery. Electricity is required to move Shasta water from the Delta to Southern California locations, including Castaic Lake and Devil Canyon. The electricity required to deliver water from the Delta to Southern California varies between 2,580 kWh to deliver an acre-foot to Castaic Lake and 3,235 kWh to deliver an acre-foot to Devil Canyon Power Plant and beyond (Department of Water Resources, 1999).

Based on the projected share of MWD's water delivered to each reach of the system, electricity use for transportation amounts to a weighted average of 2,947 kWh/AF (2.4 kWh/m^3). This includes both the use of electricity to pump water at the various pumping stations in the Central Valley and up the Tehachapis as well as the offset for electricity generated at the recovery plants on the way down from the Tehachapis. The largest pumping station is A.D. Edmonston where electricity use amounts to 2,236 kWh/AF (1.8 kWh/m^3).

Net Electricity Use. Accordingly, new electricity generation from enlarged Shasta would amount to 65,750 MWh per year, and the power used to bring water from Shasta to MWD would be 75,450 MWh per year, for a net loss of 9,700 MWh. Therefore the increase in electricity production at Shasta would almost fully compensate for the electricity needed to bring the new water to Southern California.

Energy Used for Treatment. All sources of untreated water include a cost of treatment to make water potable. However, energy use for treatment is generally considered to be a minor cost element (Lambeck, 2001). MWD's average cost of treatment is 22.7 kWh per acre-foot (0.02 kWh/m^3) treated. MWD mostly uses gravity-based treatment plants and chlorine disinfection. Other agencies may use more energy-intensive systems (e.g., osmosis), but the energy use should not be more than three times the amount that MWD uses (Lambeck, 2001).

---

[3]The estimated linear relationship was forced to go through the X-axis at 586, which is the elevation of the turbine. The difference of water elevation and turbine elevation is the "head." The relationship was used that has existed since 1997 as best representing the current configuration. The authors looked at the data for the past 20 years and found that a similar linear relationship holds.

[4]This represents an average figure prior to reservoir construction; marginal generation associated with a particular acre-foot of yield after reservoir construction will be lower.

Conservation-High Efficiency Cloths Washers

New washers would save 1.37 kWh per cycle or an estimated 536 kWh per year per washer. If five million washers were installed, this would amount to a total of 2,681,000 MWh per year or approximately 24.6 MWh per acre-foot saved (0.02 MWh/m^3). The energy savings are impressive: for each acre-foot of water "supply," new washers "yield" in savings nine times as much energy as the Shasta enlargement would require to bring water from Shasta to MWD.

Most of the energy savings from front-loading washers come from a reduction in hot water use. Because 90 percent of water heaters in California are powered by natural gas, most of the energy savings would be in natural gas. Moreover, front-loading washers remove more water from clothes during spin drying, which reduces drying times for clothes. In California, about 50 percent of clothes dryers use natural gas. Overall, approximately 20 percent of energy saved from new washers would be electricity, and 80 percent would be natural gas. In this analysis, electricity and natural gas are considered to be perfect substitutes. Based on current prices, one unit of electricity equates to about 3.5 units of natural gas.

Water Purchases

If water were purchased in the San Joaquin Valley/Tulare area, it would most likely enter the State Water Project between the Dos Amigos and the Buena Vista pumping plants. The Dos Amigos pumping plant is located on the California Aqueduct just south of the San Luis Reservoir, and the Buena Vista pumping plant is located near the junction of the Cross Valley Canal and the California Aqueduct. The energy needed to bring water from that area to Southern California is 2,271 kWh/AF (1.8 kWh/m^3). See Figure 2 for a map of California's federal, state, and local water projects (Department of Water Resources, 2002).

Transfers from the Colorado River require pumping of water from the river to Los Angeles. These transfers use 2,000 kWh/AF (1.6 kWh/m^3) (LA Department of Water and Power, 2000).

Desalination

Desalination is the most energy-intensive of thee five alternatives. For each acre-foot produced, energy use would be 5,500 kWh (4.4 kWh/m^3), twice as much as is required to bring water from Shasta or from the Central Valley to Southern California (*Orange County Register*, 2001).

Water Recycling

The Orange County Groundwater Replenishment System uses 1,700 kWh per acre-foot (2.1 Mm^3) of water treated. Treated water is injected into the ground. If reused for water supply, it would need to be pumped from the ground and retreated. As mentioned above, energy use for treatment is generally small unless the groundwater has been not chemically contaminated. Energy use for pumping would be approximately 600 kWh per acre-foot (0.5 kWh/m^3) the anticipated water depth and pumping efficiency. By way of comparison the City of Los Angeles' average energy use is 580 kWh per acre-foot (0.5 kWh/m^3) (FY 2000-2001).

Additional information about water recycling costs is offered by the San Diego Repurification project. That project is expected to use use 1,500 kWh per acre-foot (1.2 kWh/m^3) of recycled water at source. However, the recycled water would be routed directly to the water system, so no additional groundwater pumping would be required.

Sensitivity Analysis of Impact of Electricity Prices on Costs
Table 3 summarizes the five options for various electricity price assumptions. Several conclusions can be drawn from Table 3. At low energy prices (between \$20 and \$50 per MWh), transfers from the Central Valley and the Colorado River are the most economical alternatives (costing between \$300 and \$400 per acre foot (\$0.24 to \$0.32 kWh/m^3)). Surface storage, desalination, and recycling are more expensive options (costing from \$700 to \$800 per acre foot (\$0.57 to \$0.65 kWh/m^3)), and conservation (fast- or intermediate-paced) is the most expensive option considered.

The cost ranking of water supply options changes if high energy prices (between \$100 and \$150 per MWh) are assumed. In that case, conservation (the gradual program) is the cheapest option, followed by water transfers (\$500 to \$600 per acre-foot (\$0.4 to \$0.5/m^3)). If electricity prices were \$150 per MWh, the intermediate conservation program (over seven years) would even be competitive. Surface storage, recycling, and desalination are all more expensive supply options (costing more than \$700 per acre-foot (\$.6/m^3)); desalination costs more than \$1,000 per acre-foot (\$1.2 /m^3).

At the 2001 cost of energy in California (\$86 per MWh), conservation is the lowest-cost (\$82 per acre foot (\$0.07 /m^3)) and desalination the highest-cost (\$1,030 per acre foot (\$0.8 /m^3)) water source. The average cost of the long-term contracts for energy purchased by the State of California during summer of 2001 is \$86 per MWh (CA Department of Water Resources Power Purchase Contract Efforts, 2001). The other supply options would all cost between \$500 and \$700 per acre-foot (\$0.57/m^3).

Conclusions

Although CALFED and other state agencies have completed many studies to compare the cost of different water supply options, few of these studies have taken into account energy costs and benefits. We show that the price of electricity required to produce and transport water greatly influences the cost of water supply and may alter the decision maker's ranking of alternative water supply options. Our evaluation of energy costs of water supply options showed that:

- Enlargement of the Shasta reservoir is expensive compared to other options considered in this study, for a wide range of electricity prices. (We did not take into account other potential environmental benefits however). For example, Shasta is the most expensive option in this study at every energy price under \$150 per MWh. In general, water transfers, gradual conservation, and wastewater recycling are cheaper sources of water than an enlarged Shasta. Water transfers are generally the cheapest water source evaluated in this study. Apart from gradual conservation, transfers were the lowest-cost source of water at every electricity price considered.
- Water conservation through installation of new clothes washers over a period of time (the intermediate and gradual replacement programs) is a surprisingly competitive option. The higher the price of energy, the more cost effective conservation becomes. At energy prices such as those locked in by the state of California for long-term contracts (\$86 per MWh), a program of conversion to efficient washers over a 15-year period would be the lowest-cost option of those considered in the analysis.

- Wastewater recycling and desalination, which consume the most energy, show the most sensitivity to changes in the energy prices. Given very low-priced electricity ($20 per MWh), desalination and recycling are the cheapest water sources aside from transfers. Given very high-priced electricity ($150), desalination and recycling are the most expensive options. Current electricity prices under long-term contracts might justify some recycling but would probably justify little or no desalination.

Appendix: Cost of a Conservation Program to Install Efficient Washing Machines

Efficient, horizontal-axis washing machines can increase water supplies in Southern California because they save approximately 18 gallons per wash (0.06 m^3) compared to the average washing machine used in typical households. Because the average family does 392 loads of wash per year, a new washer saves 7,115 gallons (26.9 m^3) per household per year. Hence, a program to install 5 million efficient washing machines in Southern California households would save about 109,000 acre-feet (134.4 Mm^3) of water per year.

New water-conserving washing machines cost about $700, so replacing 5 million washers would cost approximately $3.5 billion. Thus, the unit cost of this program is $3,449 per acre-foot ($2.8/m^3). Unlike other options to supply Southern California, the washer conservation program would also save electricity - about 1.368 kWh per wash. Extrapolated across 5 million households, this yields savings of 2,681,000 MWh per year from this program.

Acknowledgments

The authors thank Barry Nelson, at the Natural Resources Defense Council, for initially raising many of the issues covered in this paper and follow up review. The authors are grateful to John Busch, Jim Lutz, Jim McMahon, and Ed Vine for their helpful comments.

Author's Tagline

Larry Dale, Staff Scientist/Economist, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, CA, 94720, LLDale@lbl.gov. Camilla Dunham Whitehead, Principal Research Associate, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, CA, 94720, CDWhithead@lbl.gov. Andre Fargeix, President, Golden Gate Economics, 1226 Monterey Avenue, Berkeley, CA, 94707, Andre.C.Fargeix@kp.org

Table 1 - Water Supply Option Costs: Production through Treatment
(Excluding Energy Production Benefit)

Per-Acre Water Supply Cost Comparison (1)
. Including Energy Cost at $50/MWh

	Yield	Unit Cost At Source	Transport Cost	Treatment	Total Cost (1)
	AF (m^3)	$/AF ($/m^3)	$/AF ($/m^3)	$/AF ($/m^3)	$/AF ($/m^3)
Shasta	26,000 (21)	512 (0.42)	150 (0.12)	100 (0.08)	762 (0.62)
Desalination	56,000 (45)	788 (0.64)	100 (0.08)	0	888 (0.72)
Transfer (San Joaquin Valley) (2)		200 (0.16)	110 (0.09)	100 (0.08)	410 (0.33)
Transfer (Colorado River) (2)	288,000 (233)	230 (0.19)	100 (0.08)	100 (0.08)	430 (0.35)
Conservation (washers) (fast pace)	109,000 (88)	3,449 (2.8)	0	0	3,449 (2.8)
Conservation (washers) (seven years)	109,000 (88)	2,218 (1.8)	0	0	2,218 (1.8)
Conservation (washers) (fifteen years)	109,000 (88)	986 (0.8)	0	0	986 (0.8)
Wastewater recycling (Orange County GRPS)	70,000 (57)	420 (0.34)	100 (0.08)	100 (0.08)	620 (0.5)
Wastewater recycling (San Diego Repurification)	15,000 (12)	580 (0.47)	0	100 (0.08)	680 (0.55)

Note

(1) Total cost after treatment but before distribution Total costs include the capital and O&Mcost of water supply and include electricity cost of supply.

(2) Unit costs of transfers are dry year estimates. Costs would be lower in an average year.

Table 2 Shasta Enlargement Option for Urban Use, Electricity Production and Use

		Per Year
Increase in Shasta Releases		75,400 (61) AF (m^3)
New Power Generation		**65,754 MWh**
Water Brought to MWD from Shasta		54,600 (44) AF (m^3)
of Which: New Water		25,600 (21) AF (m^3)
Electricity Use to Bring Water from Shasta to MWD	Per AF	2,947 (2.4) kWh/AF (AF/m^3)
	Total Use (new water only)	**75,453 MWh**
Net Use		**9,699 MWh**
	Per AF	0.38 (0.3) kWh/acre-foot of new water (kWh/m^3)

Table 3 Water Supply Option Total Cost per Acre-Foot for Selected Electricity Prices
(Including Energy Production Benefits)

	Yield	Base Cost	Energy	**Total Cost At Various Electricity Prices**
	AF (m^3)	$/AF	Mwh/AF	**Electricity Price in Dollar per**

		($/m^3$)	(MWh/m^3)	**MWh**				
				$20	**$50**	**$86**	**$100**	**$150**
Shasta	26,000 (24)	762 (0.62)	0.38 (0.0)	750	762	775	781	800
Desalination	56,000 (49)	888 (0.72)	5.47 (0.0)	669	833	1030	1107	1381
Transfer (San Joaquin Valley)		410 (0.33)	2.27 (0.0)	**342**	**410**	492	524	637
Transfer (Colorado River)	288,000 (235)	430 (0.35)	2.00 (0.0)	**370**	**430**	502	530	630
Conservation (washers) (fast pace)	109,000 (89)	3449 (2.8)	-24.56 (-0.02)	3239	2924	2546	2399	1874
Conservation (washers) (seven years)	109,000 (89)	2218 (1.8)	-24.56 (-0.02)	2007	1692	1314	1167	**642**
Conservation (washers) (fifteen years)	109,000 (89)	986 (0.8)	-24.56 (-0.02)	775	460	**82**	**-65**	**-590**
Wastewater recycling (Orange County)	70,000 (57)	620 (0.5)	2.30 (0.0)	528	597	680	712	827
Wastewater recycling (San Diego)	15,000 (16)	680 (0.55)	1.50 (0.0)	643	688	742	763	838

Note:
Average California residential electricity price in 2000 was $106/MWh.
Conservation:
90% of water heaters are gas-powered.
50% of clothes dryers are gas heaters.
Gas price equals electricity price divided by 3.5 (according to long-term average ratio).

Table 4. Washer Replacement Water Supply Yield

Water Savings	g/use (liter/use)	18.2 (69)
Number of uses per household	per year	392
Water Savings	g/house/annual (k-liter/house/annual)	7115 (27)
Number Households	million	5
Water Savings	g/annual (Mm^3/annual)	35574000000 (134)
Water Yield	AF/annual	109000

Table 5. Washer Replacement Electricity Yield

Energy Savings	(kWh/use)	1.368
Number of uses	(per year)	392
Energy Savings	(kWh/house/annual)	536
Number Households	(million)	5
Energy Savings	(kWh/annual)	2681000000
Energy Yield	(MWh/annual)	2681000

Figure 1 **Relationship between Mount Shasta Reservoir Elevation and Unit Electricity Production, 1997-2001**

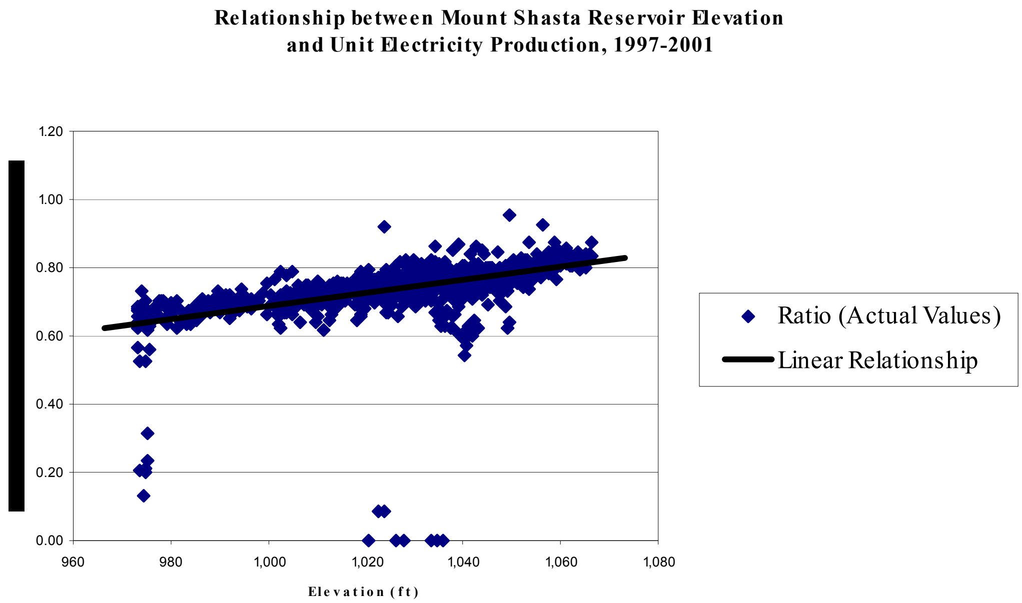

Figure 2 Map of California Water Projects

References

CALFED Bay-Delta Program. 1999. "The Economic Evaluation of Water Management Alternatives." October

California Department of Water Resources. 1980. Measuring Economic Impacts, The Application of Input-Output Analysis to California Water Resources Problems. Bulletin 210.

California Department of Water Resources. 2001. Summary of California Department of Water Resources Power Purchase Contract Efforts. page 11. Apr. 18.

California Department of Water Resources. 2002. http://wwwdwr.water.ca.gov/maps/allprojects.html. Jan. 19.

California Department of Water Resources. 2002. "Summary of California Department of Water Resources — Power Purchase Contract Efforts." http://wwwowe.water.ca.gov/newsreleases/2001/Power%20Purchase%20Efforts%204-18-01.doc . Jan. 26.

Dale, Larry. 2001. Natural Resources Defense Council."The High Cost of Surface Storage and Agricultural Willingness to Pay." Memo to the Environmental Water Caucus. Mar. 30.

Department of Water Resources, SWP Analysis Office. 1999. Kilowatt-Hours per Acre-foot Required, 9-2-99. Bulletin 132-99. Sep. 2.

Dietemann, Al. Seattle Public Utilities. 2002. Personal communication. Jan. 4.

Dietemann, Al. Seattle Public Utilities. 2002. Personal communication. Feb. 12.

Jacoby, Lee, Metropolitan Water District Of California. 2001. Personal communication. Sep. 13.

Jajliardo, Paul, City of San Diego Wastewater. 2001. Personal communication. Oct.

Lambeck, John, Metropolitan Water District Of California. 2001. Personal communication. Sep. 17.

Los Angeles Department of Water and Power. 2000. 2000 Urban Water Management Plan. page 17.

Los Angeles County Government. 2002. "Welcome to the County of Los Angeles!" http://www.co.la.ca.us/ Jan. 26.

Orange County Register. 2001. "A conversion plant is considered for Huntington." Feb. 24.

U.S. Census 2000. 2002. http://www.scag.ca.gov/census/, Jan. 4.

U.S. Department of Energy.. 2000. Final Rule Technical Support Document, Energy Efficiency Standards for Consumer Products: Clothes Washers, December.

U.S. Geological Survey. 2002. http://ca.water.usgs.gov/data/97/40425912.html, Jan. 19.